Nitrogen-stimulated algal growth in freshwater ponds of the Cape Cod National Seashore

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Abstract:

Artificial nutrient enrichment bioassays, in conjunction with sampling and analysis of surface water quality, were conducted in freshwater lakes (kettle ponds) of Cape Cod National Seashore (Massachusetts, USA) to ascertain the importance of nitrogen and phosphorus in regulating the growth of epiphytic algae. In both July and August of 2005, strong responses to additions of N+P and N alone were observed, while additions of P alone had no significant effect. These responses correspond well with low ratios (mean = 8) of dissolved inorganic nitrogen (DIN) to total phosphorus (TP) in ambient surface waters. The results suggest that conditions in the kettle ponds may develop whereby nitrogen is the primary limiting nutrient to algal productivity. While this may be a seasonal phenomenon, it has substantial implications for nutrient management in individual lakes and within the larger watershed.

Prior assumption for CCNS freshwater ponds:

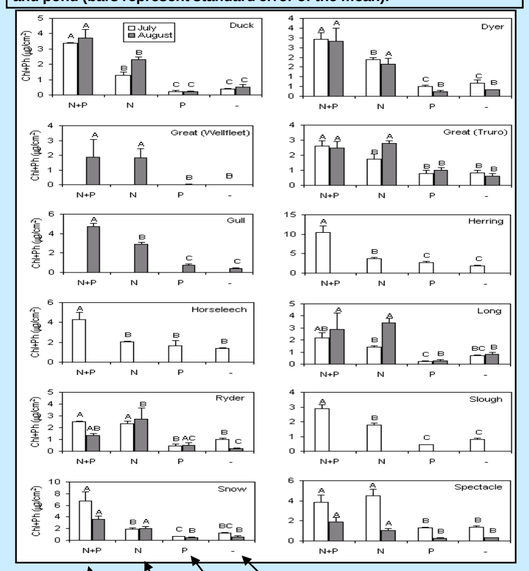
- Phosphorus regulates primary productivity (based on TN:TP molar ratios and the dogma of P-limitation in freshwater systems

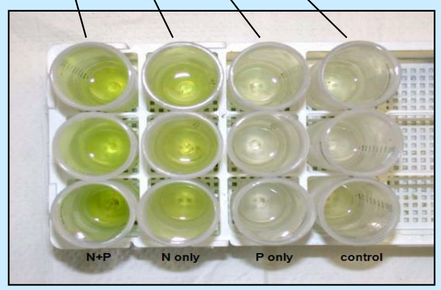
Pond	pH	ALK (mg CaCO3/l	Cond (µS/cm)	NH4-N (uM)	NOx-N (uM)	DIN (uM)	TN (uM)	PO4-P (uM)	TP (uM)	TN:TP	DIN:DIP	DIN:TP
Duck	5.1	-0.5	117	0.1	1.8	1.9	6	0.3	0.3	20	6	6
Dyer	5.1	-0.3	93	n.d.	1.0	1.0	10	0.1	0.1	96	10	10
Great (Truro)	6.6	0.5	207	0.2	1.5	1.7	14	0.1	0.1	145	17	17
Great (Wellfle	5.3	-0.2	126	n.d.	0.7	0.7	7	0.1	0.3	24	7	2
Gull	6.9	3.6	162	0.1	0.8	0.9	16	0.1	0.3	54	9	3
Herring	7.1	4.3	165	0.1	0.8	0.9	18	0.8	0.8	22	1	1
Horseleech	7.0	0.9	193	0.2	0.8	1.0	15	0.1	0.2	73	10	5
Long	5.0	-0.5	104	0.2	1.2	1.4	7	0.1	0.1	74	14	14
Ryder	6.6	0.5	148	0.2	0.8	1.0	13	0.1	0.1	127	10	10
Slough	5.1	-0.3	142	0.2	1.4	1.6	4	0.1	0.1	41	16	16
Snow	6.1	0.4	102	0.3	0.7	1.0	22	0.1	0.2	110	10	5
Spectacle	5.3	-0.2	149	0.1	0.8	0.9	13	0.1	0.2	64	9	4
(mean values)	5.9	0.7	142	0.1	1.0	1.2	12.1	0.2	0.2	71	10	8

P limitation (TN:TP)

N limitation (DIN:DIP & DIN:TP)

Chlorophyll *a* absorbance values of acetone extracts by treatment and pond (bars represent standard error of the mean).





Summary of statistically significant responses ($p \leq 0.05$) to nutrient enrichment treatments

	July			Aug		
Pond	p (N+P vs. control)	p (N vs. control)	p (P vs. control)	p (N+P vs. control)	p (N vs. control)	p (P vs. control)
Duck	<0.001	0.002	0.584	<0.001	0.002	0.601
Dyer	<0.001	0.002	0.761	0.001	0.008	0.967
Great (T)	0.007	0.096	0.998	0.002	0.001	0.355
Great (W)	-	-	-	0.026	0.012	0.999
Gull	-	-	-	0.000	<0.001	0.242
Herring	<0.001	0.034	0.418	X	X	X
Horseleech	<0.001	0.475	0.971	-	-	-
Long	<0.001	0.095	0.098	0.088	0.013	0.266
Ryder	<0.001	0.003	0.049	0.048	0.004	0.788
Slough	<0.001	0.010	0.174	-	-	-
Snow	<0.001	0.300	0.276	0.002	0.026	0.974
Spectacle	<0.001	0.001	0.998	0.006	0.099	0.987

Preliminary conclusions:

- **At times (e.g., when thermally stratified), periphyton growth is limited by N, not P**
- **Based on the N+P responses, P quickly becomes limiting once N deficiency is alleviated (co-limitation)**

Significance:

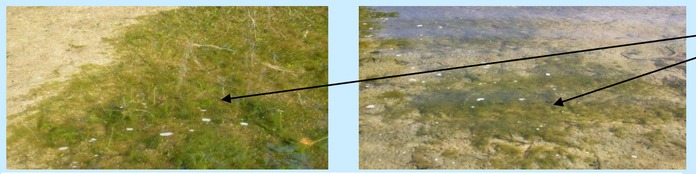
- **Both autochthonous (internal) and allochthonous (external) inputs of nitrogen may influence primary production in CACO ponds more than previously thought**
- **Management activities should target N, as well as P**

Future work:

- **What are the threshold concentrations of nitrogen that elicit responses and how do thresholds compare with quantifiable inputs (2006)?**
- **How does algal species composition change with N enrichment?**
- **Does phytoplankton behave the same way?**
- **What is the nitrogen budget of ponds (e.g., what are N losses through denitrification from the system?)**

Quantifying algal responses to controlled nutrient additions is one way to test hypotheses about nutrient regulation of primary productivity in aquatic systems. For epiphytic algae, nutrient diffusing substrates (NDS) are frequently used.

NDS Array affixed to buoy in Kettle Pond



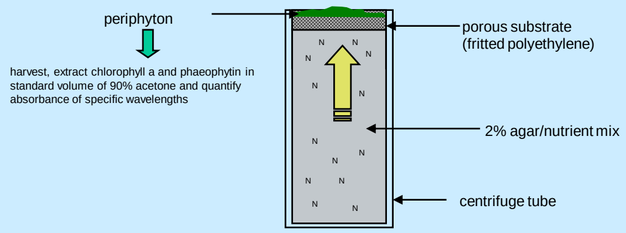
Attached Epiphytic Algae

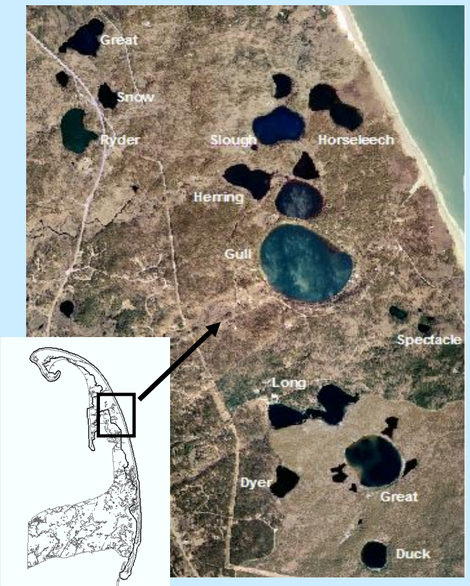
- **prevalent in shallow waters, usually attached to vegetation**
- **proportion of periphyton: phytoplankton is much higher in acidic waters**

Treatments

- **N+P** [nitrogen (0.5 M $NaNO_3$) + phosphorus (0.05 M NaH_2PO_4)]
- **N** [nitrogen only (0.5 M $NaNO_3$)]
- **P** [phosphorus only (0.05M as NaH_2PO_4)]
- **C** [control (no N or P)]

Close up of NDS
In situ periphyton bioassays (nutrient diffusing substrates):





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